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MI-63

POLYURETHANE COATING SYSTEM FOR STRUCTURAL STEEL

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

POLYURETHANE COATING SYSTEM FOR STRUCTURAL STEEL

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MARCH, 1984

SUMMARY

In order to investigate promising coating systems for existing structural steel, a laboratory evaluation of the polyurethane system was performed by the Chemicals Section. This was one of the systems described in the Canadian General Standards Board Standard No. 85-GP-13 for Painting Structural Steel for Protection Against Heavy Industrial Atmospheres. The evaluation consisted of laboratory testing of coating samples for compliance with the Standard's requirements and the determination of overall durability of the coating system based on salt spray corrosion resistance and accelerated weather resistance tests. The performance of the polyurethane system was compared with those of the currently approved Coating System 1 (two-coat high build alkyd) and Coating System 2 (inorganic zinc/vinyl).

Although the polyurethane system was considered to have excellent colour and gloss retention properties, as confirmed by laboratory testing, its performance in corrosion protection of steel was only slightly better than that of Coating System 1 currently in use but not nearly as effective as that of Coating System 2. According to the Steel Structures Painting Council (SSPC), the applied cost of the polyurethane system was estimated to be more than 1½ times that of an alkyd base system and almost equivalent to that of the inorganic zinc/vinyl system. In addition, the polyurethane system contained toxic components which were hazardous to health thus requiring stringent safety precautions during application as specified by the manufacturer.

In view of the above limitations and the potential application problems associated with two-component coating materials, the polyurethane system did not appear to be a promising coating system for existing structural steel and its use could not be recommended.

INTRODUCTION

One of the recommendations of the Task Force on Procedures for Structural Maintenance and Rehabilitation was that the Engineering Materials Office continue to investigate promising coating systems for existing structural steel on an "ongoing" basis. The coating system selected at this time for evaluation by the Chemicals Section was the polyurethane system described in the Canadian General Standards Board (CGSB) Standard 85-GP-13 for Painting Structural Steel for Protection Against Heavy Industrial Atmospheres, (August 1970). The coating system consisted of two coats of CGSB 1-GP-165M Type 1 epoxy primer and two coats of CGSB 1-GP-177M two-package polyurethane.

Although both the epoxy primer and polyurethane were two component coatings requiring near white blast cleaned steel surface preparation for optimum durability, the coating system was evaluated in order to expand on the number of coating systems suitable for application on existing structural steel. While requiring thorough surface preparation, the durability of the polyurethane system was regarded as being superior to that of the currently approved coating system 1 (two-coat high build alkyd primer/topcoat system) but less than that of coating system 2 (inorganic zinc/vinyl system). The material cost of the polyurethane system was reported to be slightly less than that of coating system 2.

At the time of this evaluation, the Canadian General Standards Board was in the process of revising the 1-GP-165 epoxy primer specification to substitute a non-lead type pigment in the formulation. Both red lead and zinc chromate pigmented epoxy primers were therefore accepted for this evaluation of the polyurethane system.

TEST MATERIALS

Invitations for submission of test samples meeting CGSB 85-GP-13 Polyurethane system were sent to fifty-five paint suppliers.

A total of seven suppliers (Appendix 2) submitted test samples of polyurethane system for evaluation.

The coating system consisted of the following CGSB coating specifications:

1-GP-165M Type 1 Primer, Epoxy, Cold Curing
The specification was modified by extending the salt spray exposure period from 240 hours specified to 1000 hours.

1-GP-177M Coating, Polyurethane, Two-Package, Resistant to Chalking and Yellowing
The specification was modified by extending the accelerated weathering exposure period from 720 hours specified to 1600 hours.

The polyurethane coating samples were required in the following CGSB 1-GP-12 c colours:

Grey 501-107
Green 503-109
Green 503-127

TEST PROCEDURE

The laboratory evaluation of the polyurethane system consisted of the testing of the materials in accordance with the general and detail requirements of the CGSB epoxy primer and polyurethane coating specifications. As previously mentioned under test materials, the accelerated weather resistance and salt spray corrosion resistance exposure periods were modified by increasing the test exposure time. For comparison, the M.T.C. two-coat high build alkyd primer/topcoat system (coating system 1) and the inorganic zinc/vinyl system (coating system 2) were included in the durability tests.

PREPARATION OF TEST PANELS

According to the surface preparation requirements of CGSB 85-GP-13, the steel surface was to be blast cleaned in accordance with SSPC-SP-10 near white blast cleaning where the polyurethane system was specified. For the salt spray and the accelerated weathering tests, the coatings were mixed and spray applied over blast cleaned steel panels according to manufacturers' recommendations (Appendix 3) where applicable as follows:

2 coats epoxy primer at approximately 37 µm dry film per coat

2 coats polyurethane topcoat approximately 37 µm dry film per coat

Minimum dry film thickness of coating system = 150 µm.

The application of the polyurethane system over previously coated steel surface was not recommended because of possible reaction between coatings and adhesion problems so that the coating system was tested over blast cleaned steel only.

For comparison the M.T.C. two-coat high build alkyd system was spray applied at 75 µm dry film thickness per coat over blast cleaned steel panels. The total applied dry film thickness of both the high build alkyd and polyurethane systems was about 150 µm. Overnight drying time between coats was allowed for application of both coating systems.

TEST METHODS

For the accelerated weathering test, the prepared test panels were cured at room temperature (25°C) at least 7 days prior to exposure for 1600 hours in the Atlas Twin Arc Weatherometer operating at 55°C to 57°C with a 102-18 cam cycle. The prepared and cured test panels in duplicate for salt spray corrosion resistance determination were exposed in the standard salt spray cabinet for 1000 hours.

One of the high build alkyd primer panels (83-SB-59) was removed from the salt spray test after 720 hours of exposure which was the maximum exposure required for this primer. The second panel (83-SB-60) was exposed for 1000 hours for comparison. The exposed test panels were evaluated in accordance with CGSB 1-GP-71 methods 122.1 and 129.1 for weatherometer and salt spray tests respectively.

The general test methods for the laboratory evaluation of the polyurethane system were those described in the following references:

CGSB 1-GP-71 Methods of Testing Paints and Pigments.

ASTM Parts 27, 28, and 29 for applicable test methods for physical and chemical analysis of coatings.

ASTM G23 Standard Recommended Practice for Operating Light - And Water - Exposure Apparatus (Carbon-Arc Type) for Exposure of Nonmetallic Materials.

ASTM D822 Standard Recommended Practice for Operating Light - And Water - Exposure Apparatus (Carbon-Arc Type) for Testing Paint, Varnish, Lacquer, and Related Products.

ASTM B117 Standard Method of Salt Spray (Fog) Testing.

Steel Structures Painting Council (SSPC Specifications).

TEST RESULTS

Laboratory physical and chemical test results of the epoxy primers and polyurethane coatings are tabulated in Tables 1 to 4. The salt spray corrosion resistance and accelerated weather resistance test results are summarized in Tables 5 to 11. Photographs of the test panels after 1000 hours of salt spray exposure and those after 1600 hours of weatherometer exposure are shown in Appendix 1, *Figures 1 to 6*. The list of test materials and the manufacturers' product data sheets are included in Appendices 2 and 3.

PHYSICAL AND CHEMICAL REQUIREMENTS

Laboratory test results of the 1-GP-165 epoxy primers (Table 1) indicated that all of the samples failed to meet one or more of the detail requirements of the specification. Three of the primers, CPI 97-48/97-98, Korzite 5070, and International ZE722017/ZE990001, appeared to be proprietary types with primer, pigment, and vehicle solids compositions which were different from those specified in 1-GP-165. The substitution of zinc chromate pigment for red lead in the primer specification was permitted but it was noted that pigment and volatile contents as well as vehicle solids composition were also modified by the three manufacturers.

The physical and chemical test results of the 1-GP-177 grey 501-107, green 503-109, and green 503-127 polyurethane coating samples (Tables 2, 3, 4) showed that all of the samples failed in one or more of the specification requirements examined. All of the polyurethane samples did not meet the impact resistance requirement possibly due to the hardness of these catalyzed coatings. There was also the possibility that this specification requirement for impact resistance was not appropriate for this type of coating. The test results indicated that many of the polyurethane coating samples failed to meet the minimum flash point requirement of the specification.

CAUTIONARY NOTES

Both the 1-GP-165 epoxy primer and the 1-GP-177 polyurethane coating are two component catalyzed materials containing flammable organic solvents and toxic components. The manufacturers' recommended safety measures should therefore be carefully followed to protect against these hazards. Skin and eye contact with both epoxy primer and polyurethane coating may cause irritation and is to be avoided. Vapours and spray mist may cause allergic and respiratory reactions. In confined areas or when spraying, it is mandatory to use a NIOSH/MSHA certified and approved air supplied respirator, according to the manufacturers, especially when applying the polyurethane coating which contains toxic isocyanates.

Adequate ventilation should be provided and an air supplied mask should also be worn to avoid breathing concentrated vapours of the epoxy primer during application in enclosed areas.

SALT/SPRAY CORROSION RESISTANCE

The CGSB specification 85-GP-13 was applicable to the preparation and coating of previously unpainted structural steel exposed to aggressive and corrosive environments. According to the specification, the steel surface preparation required for the polyurethane system consisting of two coats of 1-GP-165 epoxy primer and two coats of 1-GP-177 polyurethane coating was SSPC-SP10 near white blast cleaning, and was limited to the initial surface rust condition D maximum as shown in photograph D of SSPC Vis-1.

The salt spray resistance test was required for the 1-GP-165 epoxy primer only, however, the complete polyurethane system was also subjected to this test. The specification requirement of 240 hours of exposure in the salt spray cabinet was extended to 1000 hours for this evaluation. For comparison, the M.T.C. Coating System 1 (two-coat high build alkyd in grey and green finish coat colours) and the M.T.C. Coating System 2 (green inorganic zinc/vinyl) were included in the salt spray test.

1-GP-165 Primers

As shown in the salt spray test results (Table 5) and in the photograph (Appendix 1, *Figure 1*) of the 1-GP-165 primers, three samples appeared to meet specification requirements with respect to the degree of blistering and rust undercreepage along the scored area of the test panels. These three primer samples supplied by C.P.I., Korzite Industries, and International Paints were proprietary products which did not meet the composition requirements of specification 1-GP-165. The primers supplied by the latter two firms contained zinc chromate pigment rather than the red led pigment specified. From the salt spray test results, it appeared that zinc chromate pigmented primers performed slightly better than those containing red lead pigment.

Although the epoxy primers provided better edge corrosion protection, their overall performance was only marginally better than that of the MTC high build alkyd primer. Rust undercreepage of the scored salt spray test panels of 1-GP-165 primers appeared to be worse than that of the MTC high build zinc chromate pigmented alkyd primer.

1-GP-177 Polyurethane System

The salt spray corrosion resistance test results of the polyurethane systems (Tables 6, 7, and 8) and the photographs (Appendix 1, *Figures 2*, 3, and 4) indicated that the polyurethane system tended to blister badly along the scored area of the test panels accompanied by excessive rust formation and rust staining of the coating surface. The high build alkyd system (two panels at extreme right in *Figures 2* and 4) appeared to perform better with less rust staining under the conditions of the salt spray test while the inorganic zinc/vinyl system (two extreme right panels in *Figure 3*) performed exceptionally well in comparison with the polyurethane system. Considering the thorough steel surface preparation required and the fact that four coats were required for the polyurethane system, there appeared to be no advantage or benefit gained from the use of this coating system in the corrosion protection of steel.

ACCELERATED WEATHER RESISTANCE

The accelerated weathering test results (Tables 9, 10, and 11) showed that all of the polyurethane samples, except those from Mobil Chemical Ltd., met specification requirements with respect to coating integrity, colour and gloss change upon exposure for 1600 hours in the weatherometer. All of the Mobil polyurethane coatings failed in gloss retention upon exposure. In general, the polyurethane coating samples had better durability than the high build alkyd finish coat of Coating System 1 which showed signs of film failure such as cracking, checking and greater gloss and colour change, especially in the green finish colours. The green vinyl finish coat of Coating System 2, which had a very low initial gloss, and flat finish, did not change appreciably upon exposure in the weatherometer.

Red rust was visible in the score marks of all test sample panels except that of the inorganic zinc/vinyl reference sample.

ADVANTAGES OF THE POLYURETHANE SYSTEM

(a) It has good colour and gloss retention.

(b) It has good chemical and stain resistance properties.

(c) It has somewhat better durability than the alkyd system.

DISADVANTAGES OF THE POLYURETHANE SYSTEM

(a) It contains toxic isocyanates so that proper ventilation, air supplied respirators, gloves, etc. are required when applying this coating system.

(b) Professionally trained applicators with proper equipment are required.

(c) It is an expensive system to apply, costing approximately 1.6 times as much as the high build alkyd system with slightly better durability.

(d) It requires near white blast cleaned surface preparation and is unsuitable for application over old weathered coatings because of possible lifting due to strong solvent reaction.

(e) Both the primer and finish coats are two-component chemically cured materials, so that there are limitations with regard to pot life and curing time dependent on temperature or humidity conditions.

(f) Cured polyurethane coatings require abrading or sanding between coats to ensure satisfactory adhesion.

(g) Primer loses gloss and chalks badly on prolonged exterior exposure.

CONCLUSIONS AND RECOMMENDATIONS

According to the Steel Structures Painting Council (SSPC), the polyurethane system is considered to be superior to oil and alkyd based systems but not as effective as properly applied inorganic zinc/vinyl system for the protection of steel. The comparative applied costs of the polyurethane system and the inorganic zinc/vinyl system relative to the alkyd system are estimated by SSPC as follows:

> Polyurethane system applied cost is about 1.6 times that of the alkyd system.
>
> Inorganic zinc/vinyl system applied cost is about 1.8 times that of the alkyd system.

The applied cost of the polyurethane system is therefore almost 90% that of the inorganic zinc/vinyl system but the former is not nearly as effective in the protection of steel. Although the polyurethane system has better colour and gloss retention, chemical and stain resistance than the alkyd system, the durability of the polyurethane system, as determined by laboratory testing, appears to be only slightly better than that of the alkyd system.

The disadvantages of the polyurethane system greatly outweigh its advantages. Because of its toxicity, its high cost, potential application problems, and somewhat average durability, the use of the CGSB 85-GP-13 polyurethane system is not recommended as a coating system for existing structural steel.

TABLE 1

PHYSICAL AND CHEMICAL TEST RESULTS OF 1-GP-165 PRIMERS

Lab. Sample No.	82-50035/36	82-50041/42	82-50047/48	82-50061/63	82-50070/71	82-50072/73	82-50084/85	Specification Requirements
Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	
Code No.	13R639 A/B	97-48	4500-P-12	6070	206	103-648 A/B	ZE722017/ ZE990001	1-GP-165
Tests		(Proprietary)		(Proprietary)			(Proprietary)	
Consistency (K.U.)	81.5*	68.0	60.5	66.8	75.4	69.0	78.5	60-80
Hard dry time (hrs.)	0.25	0.75	0.5	0.25	0.4	0.35	0.3	8 max.
Fineness (Hegman)	6.0	5.5	4.5	4.0	5.5	4.5	4.0	4 min.
Gloss (60°)	1.9*	20.3	4.1*	3.1*	3.1*	5.6*	4.5*	10-30
Self-lifting	nil	nil	nil	nil	nil	nil	nil	nil
Applicability	pass	pass	pass	pass	pass	pass	pass	no sag, wrinkles
Adhesion	5	5	5	5	5	5	5	5 min.
Primer Comp. (% mass of mix)								
Pigment Content(calc.)	74.4*	34.5*	47.2*	43.4*	61.9	64.0	53.2*	60-65
Volatile matter	13.7	35.2*	31.7*	34.0*	21.4	24.8	25.6	25 max.
Pigment Comp. (% mass)								
HCl insoluble	17.4*	28.2	22.3	43.2	21.5	24.4	53.5	20 min.
Pb_3O_4	72.7*	21.7*	73.4*	nil *	74.8	75.2	nil *	75 min.
Fe_2O_3	0.8	17.6	-	6.3	-	-	0.2	not specified
ZnO	-	9.0	-	10.1	-	-	11.8	not specified
CrO_3	-	-	-	12.6	-	-	14.6	not specified
TiO_2	-	-	-	12.0	-	-	-	not specified
MgO	-	4.8	-	7.1	-	-	3.4	not specified
Heat loss (525°C)	1.7	8.8	-	-	-	-	8.3	not specified
Vehicle Solids								
Resin-α epoxide equiv.(g)	597	278*	321*	712*	654	693	657	425-700
Catalyst-amine value	230	nil*	90*	213*	237	201*	231	230-246

* Indicates failure to meet specification requirements

TABLE 2

PHYSICAL AND CHEMICAL TEST RESULTS OF 1-GP-177 POLYURETHANE COATINGS (Grey 501-107)

Lab. Sample No.	82-50038	82-50046	82-50053	82-50057	82-50066	82-50074	82-50080	Specification Requirements
Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	
Code No. Base	40-F647	Pitthane	4000-B-115	0-5785	X2589A	103-777	ZE396804	1-GP-177
Catalyst	40-T2	97-819	4000-C-1	0-5787	X2594	Part B	ZE990011	
Test								
Consistency (K.U.)								
15 mins. after mixing	64.5	55.2*	48.0*	60.6	69.4	65.0	62.8	60-80
4 hours after mixing	64.8	57.2	83.5	74.2	70.7	74.5	101.3*	95 max.
Dry time (hours)								
Touch dry	0.05	0.1	0.5	0.2	0.5	0.07	0.4	1 hour max.
Hard dry	0.1	0.3	2.6	1.25	6.0	0.3	2.1	18 hour max.
Fineness (Hegman)	7.0	7.0	7.0	7.0	7.0+	7.0	7.0+	6 min.
Gloss (60°)	89	86	93	93	96	95	96	85 min.
Flash Point (°C)	18*	24*	17*	29	37	26*	35	27°C min.
Hiding Power (125 µm)	pass	pass	pass	pass	pass	pass	pass	black and white squares
Scrubability (5000 cycles)	pass	pass	pass	pass	pass	pass	pass	slight difference
Applicability	pass	pass	pass	pass	pass	pass	pass	no sags or wrinkles
Flexibility (mandrel)	fail*	fail*	pass	fail*	pass	pass	pass	pass 3.2 mm
Impact Resist. (J)	1.3*	0.2*	2.6*	0.8*	0.2*	0.1*	0.4*	4.5 J min.
Water Resist. (23°C)	pass	pass	pass	pass	pass	pass	pass	pass
Volatile matter % by mass	38.3	49.0*	45.8	38.1	31.5	35.7	35.0	45% max. of mix

* indicates failure to meet specification requirements

TABLE 3

PHYSICAL AND CHEMICAL TEST RESULTS OF 1-GP-177 POLYURETHANE COATINGS (Green 503-109)

Lab. Sample No.	82-50040	82-50044	82-50049	82-50058	82-50068	82-50076	82-50081	Specification Requirements
Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	
Code No. Base	40-G677	Pitthane	4000-G-66	0-5786	X2591	103-786	ZE395803	1-GP-177
Catalyst	40-T2	97-819	4000-C-1	0-5787	X2594	Part B	ZE990011	
Tests								
Consistency (K.U.)								
15 mins. after mixing	68.6	54.8*	51.3*	54.2*	75.0	75.9	59.8	60-80
4 hours after mixing	69.5	56.6	83.0	55.2	81.2	86.1	121.7*	95 max.
Dry time (hours)								
Touch dry	0.05	0.2	0.5	0.3	0.25	0.1	0.5	1 hour max.
Hard dry	0.2	0.4	3.3	2.5	6.25	6.3	2.2	18 hour max.
Fineness (Hegman)	7.0	6.5	7.0	7.0	7.0+	7.0+	7.0+	6 min.
Gloss (60°)	78*	87	94	93	90	89	95	85 min.
Flash Point (°C)	12*	24*	20*	20*	30	26*	30	27°C min.
Hiding Power (125 µm)	pass	pass	pass	pass	pass	pass	pass	black and white squares
Scrubability (5000 cycles)	pass	pass	pass	pass	pass	pass	pass	slight difference
Applicability	pass	pass	pass	pass	pass	pass	pass	no sags or wrinkles
Flexibility (mandrel)	fail*	fail*	pass	pass	fail*	pass	pass	pass 3.2 mm
Impact Resist. (J)	3.2*	0.3*	2.5*	0.7*	0.4*	0.1*	1.5*	4.5 J min.
Water Resist. (23°C)	pass	pass	pass	pass	pass	pass	pass	pass
Volatile matter % by mass	37.4	50.7*	39.8	41.1	32.6	32.8	35.2	45% max. of mix

* Indicates failure to meet specification requirements

TABLE 4

PHYSICAL AND CHEMICAL TEST RESULTS OF 1-GP-177 POLYURETHANE COATINGS (Green 503-127)

Lab. Sample No.	82-50039	82-50045	82-50051	82-50060	82-50067	82-50078	82-50082	Specification Requirements
Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	
Code No. Base	40-G678	Pitthane	4000-G-67	0-5788	X2590	103-787	ZE395804	1-GP-177
Catalyst	40-T2	97-819	4000-C-1	0-5787	X2594	Part B	ZE990011	
Tests								
Consistency (K.U.)								
15 mins. after mixing	70.0	51.8*	56.0*	62.7	75.2	71.0	56.7*	60-80
4 hours after mixing	70.7	53.8	77.5	93.7	82.8	88.1	102.2*	95 max.
Dry time (hours)								
Touch dry	0.05	0.2	0.5	0.2	0.6	0.07	0.3	1 hour max.
Hard dry	0.2	0.3	3.2	0.9	6.3	0.3	1.9	18 hour max.
Fineness (Hegman)	7.0	7.0	7.0	7.0	7.0+	7.0	7.0+	6 min.
Gloss (60°)	68*	81*	92	93	94	89	96	85 min.
Flash Point (°C)	14*	25*	15*	25*	35	25*	30	27°C min.
Hiding Power (125 µm)	pass	pass	pass	pass	pass	pass	pass	black and white squares
Scrubability (5000 cycles)	pass	pass	pass	pass	pass	pass	pass	slight difference
Applicability	pass	pass	pass	pass	pass	pass	pass	no sags or wrinkles
Flexibility (mandrel)	fail*	fail*	pass	pass	pass	fail*	pass	pass 3.2 mm
Impact Resist. (J)	2.1*	0.7*	3.8*	0.7*	0.7*	0.1*	1.0*	4.5 J min.
Water Resist. (23°C)	pass	pass	pass	pass	pass	pass	pass	pass
Volatile matter % by mass	39.0	55.8*	31.4	38.5	30.4	38.7	42.0	45% max. of mix

* Indicates failure to meet specification requirements

TABLE 5

SALT SPRAY TEST RESULTS OF 1-GP-165 EPOXY PRIMER

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	C.P.I.
Panel No.	83-SB-01/02	83-SB-09/10	83-SB-17/18	83-SB-25/26	83-SB-33/34	83-SB-41/42	83-SB-49/50	83-SB-59/60
Colour	Orange	Red-brown	Orange	Yellow	Orange	Orange	Yellow	Yellow high build
Coating thick (µm)	76	86	84	84	84	86	84	79
Exposure(hrs.)								
500	Bl.#4M (along score) Bl.#4F (face) Light med. rust in score	Bl.#2F (score) med.-heavy black	Bl.#7M (face) med. rust in score	Bl.#6F (score) med.-heavy rust in score	Bl.#6F (score) med.-heavy black rust in score	Bl.#4MD (face) med. black rust in score	Bl.#8M (face) light rust in score	Bl.#4M (face) med. heavy rust in score
1000	Bl.#4M (score) Bl.#6MD (face) med. rust in score Edge rusting Rust stain 10-15% of panel	Bl.#2M (score) Bl.#8M (face) med. heavy rust Rust stain 5-10%	Bl.#2MD (score) Bl.#6MD (face) med. heavy rust Rust stain 3-5%	Bl.#4M (score) Bl.#8F (face) med. heavy rust Rust stain 5-8%	Bl.#2-4MD (score) Bl. nil (face) med. heavy rust Edge rusting Rust stain 5%	Bl.#4D (score) Bl.#4MD (face) med. heavy rust Rust stain 1-3%	Bl.#6M (score) Bl.#8M (face) med. heavy rust Edge rusting Rust stain 1-5%	Bl.#2MD (score) Bl.#4M (face) Heavy rust in score Edge rusting Rust stain 10%
Rust creep (mm)	2.0	1.5	2.0	1.0	3.0	3.0	1.5	1.5
Specification Requirements:	Blister 8M max. 1.5 mm max. undercreepage							

Bl. = Blister rating ASTM D714 Standard Method of Evaluating Degree of Blistering of Paints

TABLE 6

SALT SPRAY TEST RESULTS OF 1-GP-177 POLYURETHANE SYSTEM Grey 501-107

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	Sterling/C.P.I (coating Syst1)
Panel No.	83-SB-04	83-SB-12	83-SB-20	83-SB-28	83-SB-36	83-SB-44	83-SB-52	83-SB-62
Coating thick (µm)	150	170	160	165	170	170	155	165
Exposure(hrs.)								
500	Bl.#6F (along score) med. black rust in score	Bl.#4F (score) med. black rust in score	Bl.#4F (score) med. rust in score	Bl.#8F (score) med. rust in score	Bl.#6F (score) med. black rust in score	Bl.#6F (score) med. black rust in score	Bl.#7F (along score) sl. rust in score	Bl.#4F (score) med. rust in score
1000	Bl.#4F (score) Bl.#9F(face) med. heavy rust Sl. edge rust Rust stain 5-10%	Bl.#2F (score) Bl. nil(face) med. heavy black rust Rust stain 5%	Bl.#2M (score) Bl. nil(face) med. rust Rust stain 1-3%	Bl.#4MD (score) Bl. nil(face) med. heavy rust Rust stain 3-5%	Bl.#2M (score) Bl. nil(face) med. rust Rust stain 3-5%	Bl.#2M (score) Bl. nil(face) med. rust Black rusted blisters Rust stains 15-20%	Bl.#6M (score) Bl.#9M (face) Light med. rust Rust stain 1-3%	Bl.#4M (score) Bl. nil(face) med. rust Rust stain 1%
Rust creep (mm)	2.0	2.0	2.0	1.0	3.0	2.5	1.0	0.5

Bl. = Blister rating ASTM D714 Standard Method of Evaluating Degree of Blistering of Paints

TABLE 7

SALT SPRAY TEST RESULTS OF 1-GP-177 POLYURETHANE SYSTEM Green 503-109

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	Ameron (Coating Syst. 2)
Panel No.	83-SB-07/08	83-SB-15/16	83-SB-23/24	83-SB-31/32	83-SB-37/38	83-SB-47/48	83-SB-55/56	83-SB-57/58
Coating thick (µm)	155	162	160	165	173	150	150	224
Exposure(hrs.)								
500	Bl.#6F (face) med. black rust in score Edge rusting	Bl.#2F (score) med. heavy rust in score	Bl.#4F (score) Light med. rust in score	Bl.#8F (score) med. rust in score	Bl.#2F (score) Light med. rust in score	Bl.#4F (score) med. heavy rust in score	Bl.#7F (score) Light med. rust in score	White zinc oxides in score
1000	Bl.#4 (score) Bl.#4M (face) med. black rust Edge rust Rust stain 3-5%	Bl.#2F (score) Bl.#6F (face) Heavy black rust Rust stain 5%	Bl.#2M (score) Bl.#8MD(face) Light med. black rust Rust stain 1-3%	Bl.#4M (score) Bl. nil(face) med. heavy rust Rust stain 3-5%	Bl.#2M (score) Bl. nil(face) Light black rust Rust stain 1-3%	Bl.#2M (score) Bl. nil(face) med. heavy rust Rust stain 3-5%	Bl.#6M (score) Bl.#6F (face) Light black rust Rust stain 1-3%	Bl. nil (score,face) White zinc oxides in score No rust
Rust creep (mm)	2.0	1.5	2.0	1.0	3.0	2.0	1.0	0

Bl. = Blister rating ASTM D714 Standard Method of Evaluating Degree of Blistering of Paints

TABLE 8

SALT SPRAY TEST RESULTS OF 1-GP-177 POLYURETHANE SYSTEM Green 503-127

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	Sterling/C.P.I. (Coating Syst. 1)
Panel No.	83-SB-06	83-SB-14	83-SB-22	83-SB-30	83-SB-40	83-SB-46	83-SB-54	83-SB-64
Coating thick (µm)	150	158	162	162	175	165	155	165
Exposure(hrs.)								
500	Bl.#6F (face) med. black rust in score Bl.#6D along edges	Bl.#2F (score) Heavy black rust in score	Bl.#2F (score) med. rust in score	Bl.#8 (score) Light med. rust in score	Bl.#2F (score) med. rust in score	Bl.#4F (score) med. heavy rust in score	Bl.#7F (score) Light med. rust in score	Bl.#4F (score) Bl.#2M(bottom) med. heavy rust in score
1000	Bl.#2MD (score) Bl.#2MD(face) med. rust in score Edge rusting Rust stain 5-10%	Bl.#2M (score) Bl. nil(face) Heavy rust Rust stain 5%	Bl.#2MD (score) Bl. nil(face) Rust stain 1-3%	Bl.#4M (score) Bl. nil(face) med. heavy rust Rust stain 1-3%	Bl.#2MD (score) Bl. nil(face) med. heavy rust in score Rust stain 1-3%	Bl.#2M (score) Bl.#8M (face) Heavy rust in score Rust stain 3-5%	Bl.#4M (score) Bl.#6M (face) med. heavy rust in score Rust stain 1-3%	Bl.#4M (score) Bl.#6M (face) Edge rusting Rust stain 1-3%
Rust creep (mm)	1.0	1.0	2.0	1.0	2.0	1.5	1.0	0.5

Bl. = Blister rating ASTM D714 Standard Method of Evaluating Degree of Blistering of Paints

TABLE 9

WEATHEROMETER TEST RESULTS OF 1-GP-177 POLYURETHANE SYSTEM Grey 501-107

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	Sterling/C.P.I.
Panel No.	83-WB-03	83-WB-11	83-WB-19	83-WB-27	83-WB-35	83-WB-43	83-WB-51	83-WB-61
Coating thick (µm)	165	188	180	180	190	183	165	183 (coating Syst. 1)
Exposure(hrs.)								
0	Gloss 75	Gloss 89	Gloss 97	Gloss 96	Gloss 95	Gloss 94	Gloss 95	Gloss 82
500	Gloss 62 E = 0.76	Gloss 68 E = 0.42	Gloss 72 E = 0.99	Gloss 78 E = 0.32	Gloss 83 E = 0.87	Gloss 77 E = 0.51	Gloss 82 E = 0.86	Gloss 48 E = 3.25
1200	Gloss 41 E = 0.41	Gloss 68 E = 0.37	Gloss 76 E = 0 37	Gloss 63 E = 0.32	Gloss 80 E = 0.20	Gloss 68 E = 0.22 Pinholing	Gloss 68 E = 0.92	Gloss 22 Check 7, Crack 9 E = 3.96
1600	Gloss 41 E = 1.05 Low gloss	Gloss 71 E = 1.02	Gloss 70 E = 0.79	Gloss 58 E = 0.85	Gloss 73 E = 0.95	Gloss 74 E = 0.60	Gloss 64 E = 2.70	Gloss 10 Check 6, Crack 8 E = 7.85 darker colour
Specification Requirements:	No blistering, cracking, flaking, peeling or chalking after exposure Gloss after exposure: 60 minimum							

Gloss Rating: ASTM D523, Colour Difference (E): ASTM D2244, Cracking: ASTM D661, checking: ASTM D660

TABLE 10

WEATHEROMETER TEST RESULTS OF 1-GP-177 POLYURETHANE SYSTEM Green 503-109

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	Ameron
Panel No.	83-WP-07	83-WP-15	83-WB-23	83-WB-31	83-WB-37	83-WB-47	83-WB-55	83-WB-57
Coating thick (µm)	165	178	175	183	188	165	168	244 (Coating Syst.2)
Exposure(hrs.)								
0	Gloss 40	Gloss 89	Gloss 94	Gloss 97	Gloss 90	Gloss 90	Gloss 94	Gloss 2
500	Gloss 30 E = 1.30	Gloss 81 E = 1.35	Gloss 75 E = 1.18	Gloss 80 E = 1.56	Gloss 62 E = 2.03	Gloss 66 E = 1.93	Gloss 72 E = 1.76	Gloss 1.1 E = 3.98
1200	Gloss 27 E = 1.56	Gloss 73 E.= 1.05	Gloss 68 E = 1.28	Gloss 75 E = 1.08	Gloss 61 E = 1.82	Gloss 73 E = 1.96 Pinholing	Gloss 68 E = 1.62	Gloss 0.9 E = 3.11
1600	Gloss 23 E = 0.49 Low gloss	Gloss 75 E = 1.00	Gloss 74 E = 1.40	Gloss 69 E = 1.37	Gloss 67 E = 1.93	Gloss 63 E = 1.98	Gloss 67 E = 1.80	Gloss 0.9 E = 3.16 slight fading

Specification Requirements: No blistering, cracking, flaking, peeling, or chalking after exposure
Gloss after exposure: 60 minimum

Gloss Rating: ASTM D523, Colour Difference (E): ASTM D2244, Cracking: ASTM D661, checking: ASTM D660

TABLE 11

WEATHEROMETER TEST RESULTS OF 1-GP-177 POLYURETHANE SYSTEM Green 503-127

Manufacturer	Mobil	C.P.I.	Tempo	Korzite	All Colour	Niagara	International	Sterling/C.P.I.
Panel No.	83-WB-05	83-WB-13	83-WB-21	83-WB-29	83-WB-39	83-WB-45	83-WB-53	83-WB-63
Coating thick (µm)	168	178	178	173	190	180	170	180 (Coating Syst. 1)
Exposure(hrs.)								
0	Gloss 42	Gloss 85	Gloss 85	Gloss 92	Gloss 91	Gloss 86	Gloss 95	Gloss 87
500	Gloss 34 E = 2.31	Gloss 72 E = 1.97	Gloss 82 E = 2.09	Gloss 69 E = 2.15	Gloss 67 E = 2.98	Gloss 66 E = 3.48	Gloss 78 E = 2.57	Gloss 59 E = 3.57
1200	Gloss 14 E = 4.31 darker	Gloss 63 E = 2.70	Gloss 76 E = 2.15	Gloss 68 E = 2.29	Gloss 67 E = 2.44	Gloss 63 E = 3.03 Pinholing	Gloss 77 E = 2.57	Gloss 57 E = 4.17 fading
1600	Gloss 17 E = 4.28 dull finish	Gloss 57 E = 1.79	Gloss 75 E = 0.88	Gloss 69 E = 2.09	Gloss 67 E = 3.09	Gloss 67 E = 3.10	Gloss 80 E = 2.76	Gloss 49 E = 4.82 starting to check and crack

Specification Requirements: No blistering, cracking, flaking, peeling, or chalking after exposure
Gloss after exposure: 60 minimum

Gloss Rating: ASTM D523, Colour Difference (E): ASTM D2244, Cracking: ASTM D661, Checking: ASTM D660

APPENDIX 1

Salt Spray Test Panels of Polyurethane Systems After 1000 Hours of Exposure

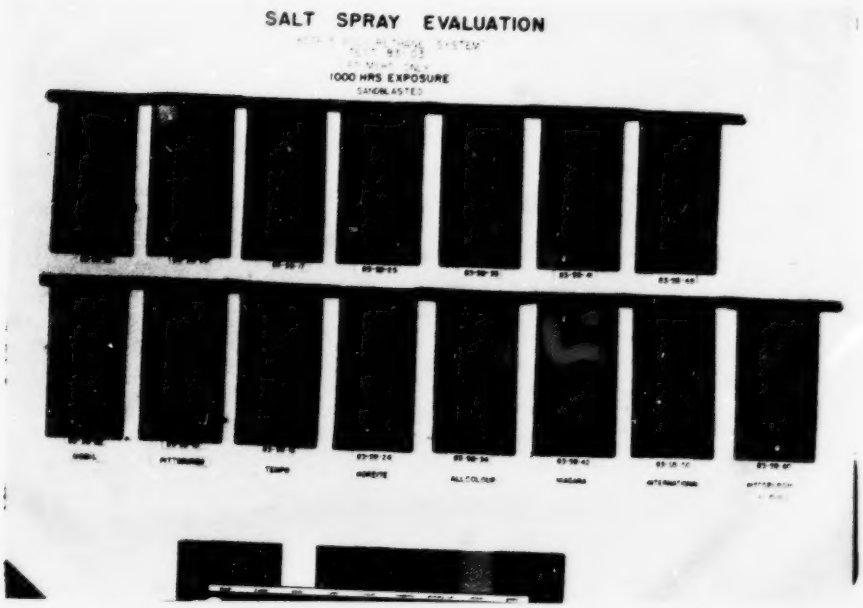

FIG. 1 *Epoxy Primers only (extreme right). Reference panel of high build alkyd primer.*

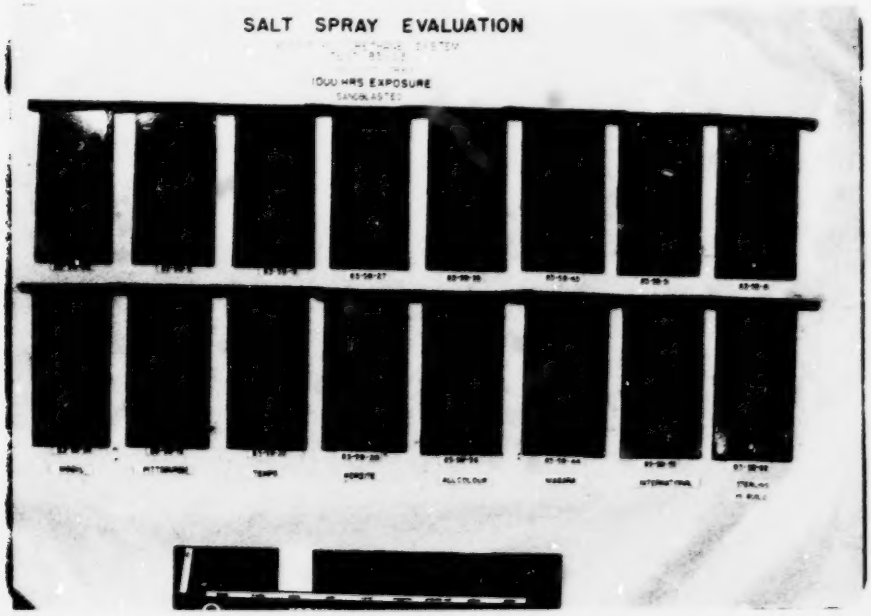

FIG. 2 *Grey 501-107 Polyurethane System (4 coats). (extreme right) Reference panels of Coating System 1 - hgih buildin alkyd (2 coats).*

Salt Spray Test Panels of Polyurethane Systems After 1000 Hours of Exposure

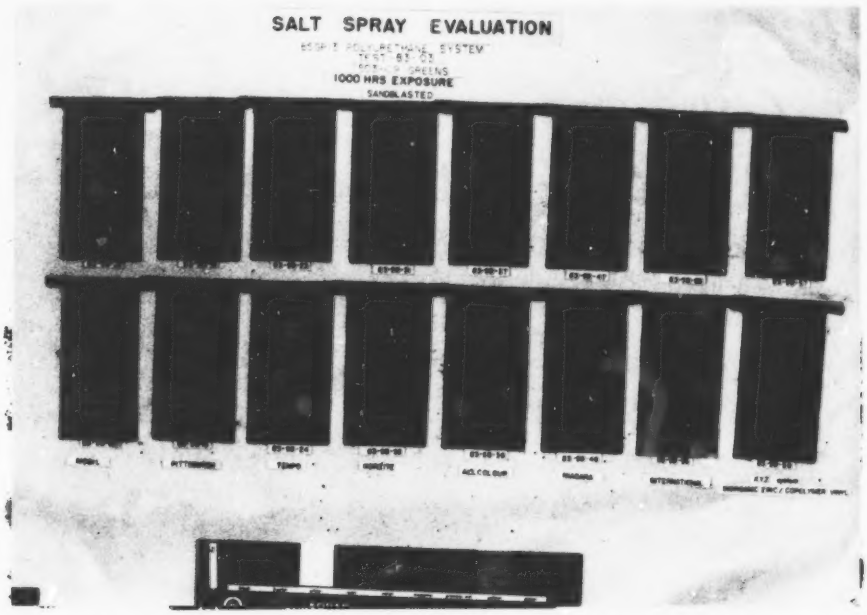

FIG. 3 *Green 503-109 Polyurethane Systems (4 coats). (extreme right) Reference panels of coating system 2 inorganic zinc/vinyl (4 coats)*

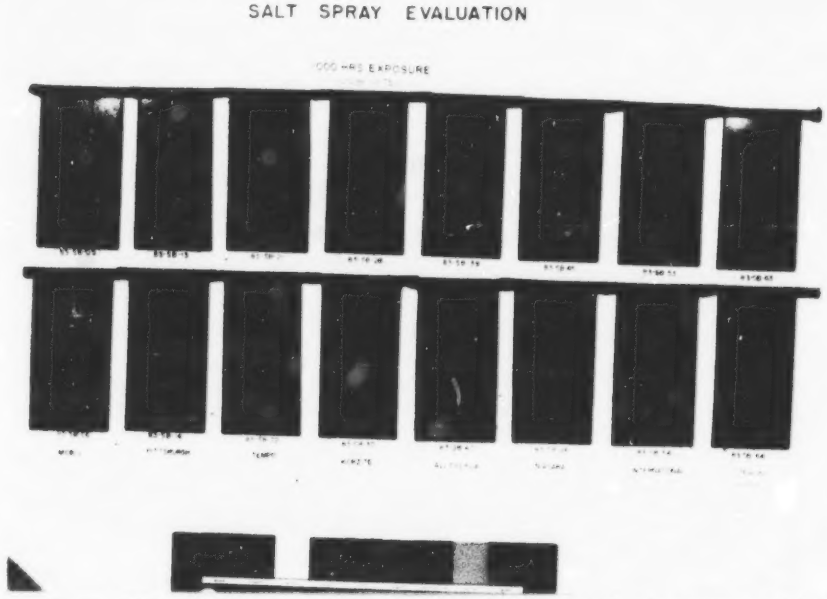

FIG. 4 *Green 503-127 Polyurethane Systems (4 coats). (extreme right) Reference panels of Coating System 1 - high building alkyd (2 coats)*

Weatherometer Test Panels of Polyurethane Systems After 1600 Hours of Exposure

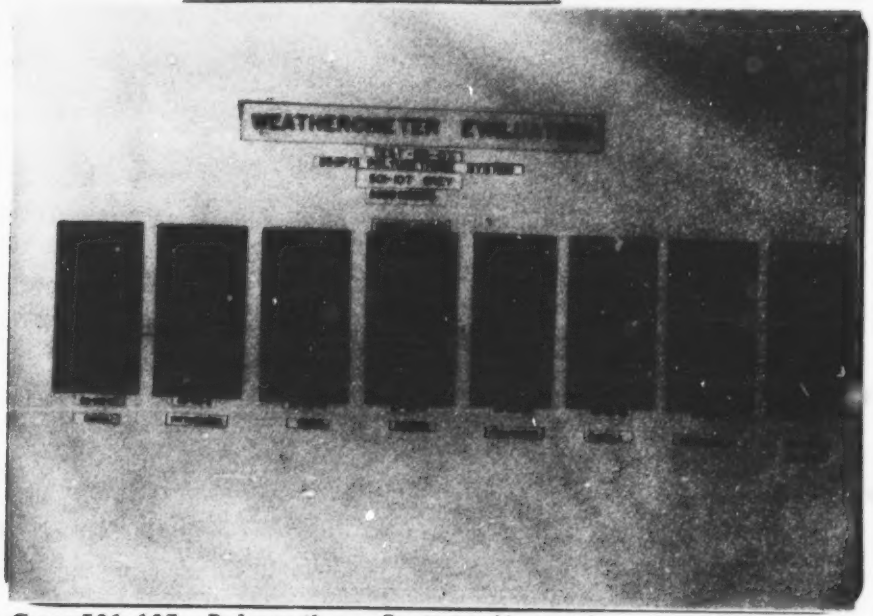

FIG. 5 Grey 501-107. Polyurethane Systems (4 coats). (extreme right). Reference panel of Coating System 1 high build alkyd (2 coats)

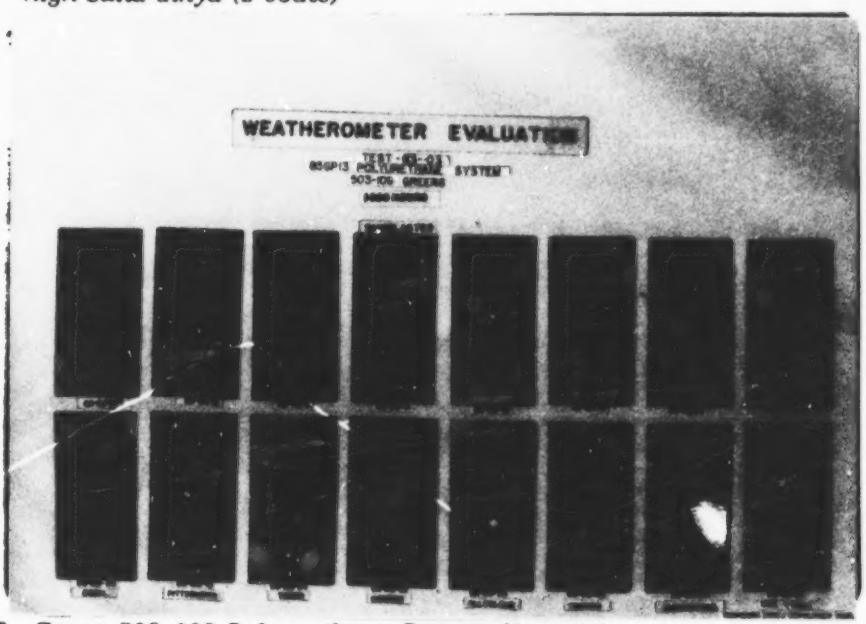

FIG. 6 Green 503-109 Polyurethane System (4 coats) (extreme right). Reference panel of Coating System 2 inorganic zinc/vinyl (4 coats)

APPENDIX 2

List of Test Samples
85 GP 13 Polyurethane System

Sample #	Manufacturer	Code	Product
82-S-50035	Mobil	13-R639B	Curing agent for 13-R639A
-50036	Mobil	13-R639A	Red lead epoxy primer
-50037	Mobil	40-T2	Urethane Curing agent
-50038	Mobil	40-F647	(501-107) Mobilthane enamel Grey
-50039	Mobil	40-G678	(503-127) Mobilthane enamel Green
-50040	Mobil	40-G677	(503-109) Mobilthane enamel Green
82-S-50041	Pittsburgh	97-48	Aquapon Red Primer (contains lead)
-50042	Pittsburgh	97-99	Catalyst for 97-48
-50043	Pittsburgh	97-810	Clear Curing agent
-50044	Pittsburgh		503-109 Pitthane Acrylic-Urethane Enamel, Green
-50045	Pittsburgh		503-127 Pitthane Acrylic-Urethane Enamel, Green
-50046	Pittsburgh		501-107 Pitthane Acrylic-Urethane Enamel, Grey
82-S-50047	Tempo	4500-P-12	Type 1 Epoxy Primer Orange
-50048	Tempo	4500-C-12	Epoxy Primer Catalyst
-50049	Tempo	4000-G-66	503-109 Polyurethane Green
-50050	Tempo	4000-C-1	Catalyst for G-66 Polyurethane
-50051	Tempo	4000-G-67	503-127 Polyurethane Green
-50052	Tempo	4000-C-1	Catalyst for G-67 Polyurethane
-50053	Tempo	4000-B-115	501-107 Polyurethane Grey
-50054	Tempo	4000-C-1	Catalyst for B-115
-50055	Tempo	4600-S-1	Polyurethane Thinner
-50056	Tempo	4500-S-23	Epoxy Primer Thinner
82-S-50057	Korzite	0-5785	501-107 Urethane Grey
-50058	Korzite	0-5786	503-109 Urethane Green
-50059	Korzite	0-5787	Urethane Activator
-50060	Korzite	0-5788	503 127 Urethane Green
-50061	Korzite	# 6070	Yellow Zinc Chromate Primer
-50062	Korzite	7673	Epoxy Thinner for #6070 Primer
-50063	Korzite		Activator for #6070 Primer
-50064	Korzite	9033	Durabrite Thinners

APPENDIX 2

List of Test Samples

85 GP 13 Polyurethane System

Sample #	Manufacturer	Code	Product
82-S-50066	All Colour	X2589A	501-107 Brushing Urethane Base Grey
-50067	All Colour	X2590	503-127 Brushing Urethane Base Green
-50068	All Colour	X2591	503-109 Brushing Urethane Base Green
-50069	All Colour	X2594	Brushing Urethane Curing agent
-50070	All Colour	206	Red Lead Epoxy 12-2006 Primer Base
-50071	All Colour	206	Red Curing agent 99-0048 Type 1
82-S-50072	Niagara	103-649	Part A Red Lead Primer
-50073	Niagara	103-648	Part B for Red Lead Primer
-50074	Niagara	103-777	501-107 Grey Polycoating Part A
-50075	Niagara	103-777	501-107 Grey Polycoating Part B
-50076	Niagara	103-786	503-109 Green Urethane Enamel Part A
-50077	Niagara	103-786	503-109 Green Urethane Enamel Part B
-50078	Niagara	103-787	503-127 Green Urethane Enamel Part A
-50079	Niagara	103-787	503-127 Green Urethane Enamel Part B
82-S-50080	International	ZE396804	501-107 Grey Interthane PF 2 Base: 1 Reactor by Vol.
82 -50081	International	ZE395803	503-109 Green Interthane PF 2 Base: 1 Reactor by Vol.
-50082	International	ZE395804	503-127 Green Interthane PF 2 Base: 1 Reactor by Vol.
-50083	International	ZE990011	Interthane CC Reactor
-50084	International	ZE722017	Yellow Intergard CC Primer 3:1 with ZE990001
-50085	International	ZE990001	Intergard EPA 301 Curing agent
-50086	International	ZE073494	Thinner for Intergard Primer
-50087	International	ZE073457	Thinner for Interthane Finish

APPENDIX 3

Manufacturers'
Product Data Sheets

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